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INSTRUMENTATION OF NATIONAL PHYSICAL LABORATORY

FATIGUE TESTING MACHINE

N.J. Baldwin, D.S. Saunders and N.M. Burman

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INSTRUMENTATION OF NATIONAL PHYSICAL LABORATORY FATIGUE TESTING MACHINE

N.J. Baldwin, D.S. Saunders and N.M. Burman

ABSTRACT

A National Physical Laboratory fatigue testing machine used for the fatigue pre-cracking of Charpy-sized test specimens has been instrumented. It is now possible to monitor crack growth electronically thereby reducing the operator's time in attendance at the machine from hours to minutes and improving the reproducibility of fatigue pre-cracking.

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16. ABSTRACT (if this is security classified, the announcement of this report will be similarly classified):

A National Physical Laboratory fatigue testing machine used for the fatigue pre-cracking of Charpy-sized test specimens has been instrumented. It is now possible to monitor crack growth electronically thereby reducing the operator's time in attendance at the machine from hours to minutes and improving the reproducibility of fatigue pre-cracking.

C O N T E N T S

* * *

INSTRUMENTATION OF NATIONAL PHYSICAL LABORATORY FATIGUE TESTING MACHINE

1. INTRODUCTION

The National Physical Laboratory (NPL) fatigue testing machine* is used in this laboratory to fatigue pre-crack and/or fatigue test small specimens approximately conforming to Charpy test specimen dimensions. In the past, fatigue pre-cracking and testing of these specimens has been both inaccurate and time consuming, and required the continual attendance of an operator. Fatigue crack initiation and growth were monitored and measured optically, and there was no provision for measuring the deflection of the specimen due to the load applied by the machine.

This report describes the modifications which have been made to the NPL fatigue testing machine to allow:

(i) Measurement of the compliance of the system which reflects crack extension in the specimen under test

(ii) A facility to automatically switch the machine off when the crack reaches a pre-determined length.

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* NPL combined fatigue stress testing machine constructed to the design of the National Physical Laboratory, Teddington England, by Coventry Gauge & Tool Co Ltd, Coventry England.

2. THE NPL MACHINE

The NPL machine is illustrated schematically in Figure 1. A wheel with eccentrically located weights is attached to the lower four cantilever bars and, on rotation, applies a sinusoidal force to the upper cantilever system via two vertical connecting rods. The Charpy test specimen is held rigidly at one end and clamped into the upper cantilever arm at the other. Thus, the specimen forms part of the upper cantilever system and hence undergoes cyclic loading, the mode of which is predominantly bending. The cantilever arm has a relatively large cross-sectional area, consequently the bending stress levels in it are low compared to those of the specimen.

3. THE INSTRUMENTATION OF THE NPL MACHINE

The machine is instrumented by attaching strain gauges to two of the lower cantilever bars in a single, full bridge configuration, see Figures 1 and 2. The voltage applied to the bridge is 6V DC. The sinusoidal output from the strain bridge is amplified (gain = 100) and then displayed on a digital voltmeter. This output is also monitored by the electronic circuitry shown in Figure 3 which, when a chosen pre-set AC voltage level is reached, shuts down the fatigue machine allowing the final stages of crack growth to be finely controlled by manual operation. The circuit measures peak voltage but is calibrated in RMS voltage levels.

The AC RMS voltage level is related to the displacement of the lower cantilever bars, and hence measures the compliance of the system. As the fatigue crack grows in the specimen the compliance of the system increases commensurate with an increase in cantilever bar deflection and strain bridge output.

4. VALIDATION OF INSTRUMENTATION

For validation purposes only, notched and unnotched dummy specimens were prepared with strain gauges mounted on the back face of each specimen below the notch region, as shown in Figure 4. Clearly, the output voltage from these gauges is closely related to notch depth in the specimen. Tests were then carried out to compare the output voltage levels from the strain gauges attached to the lower cantilever bars and the dummy specimens. The results for various out-of-balance weights with a series of specimens of notch depths 1.7, 3.1 and 5 mm and notch radii of 1 mm are shown in Figure 4. This figure shows the correlation between the two output voltage levels. It is evident that the voltage output from the strain gauges on the lower cantilever bars does relate closely to the strain in the specimen under test.

Using the same test results, the difference between the notched and unnotched AC RMS voltage outputs (ΔV) from the lower cantilever bars is plotted against the ratio of notch depth (a) to specimen width (w) in Figure 5. The curves clearly show that it is possible to monitor crack extension in terms of a change in output voltage from the lower cantilever bars for specific out-of-balance weights.

5. PRACTICAL CONSIDERATIONS

For any series of tests the first specimen is used to evaluate the pre-set voltage levels required for the growth of cracks to a specific depth. Figure 6 is a graph of change in AC RMS voltage output from the cantilever bars plotted against a/w for one first specimen in a series of Charpy-sized specimens fatigue pre-cracked using the modified NPL machine. Similar changes in AC voltage levels were recorded for all the specimens in this series where the fatigue pre-cracks were taken to a/w = 0.45.

Since the modification of this machine, a large number of Charpy-sized fracture toughness specimens has been fatigue pre-cracked. During fatigue pre-cracking, operator involvement was found to be only about 20 min of the 4 h of machine operation for each of the specimens in the particular series undertaken. This represents a considerable saving in operator time.

6. SUMMARY

By instrumenting a National Physical Laboratory fatigue testing machine it is now possible to measure stress levels in specimens and to monitor crack growth electronically. This in turn results in improved reproducibility of fatigue pre-cracking of Charpy sized specimens and a reduction of operator attendance from hours to minutes.

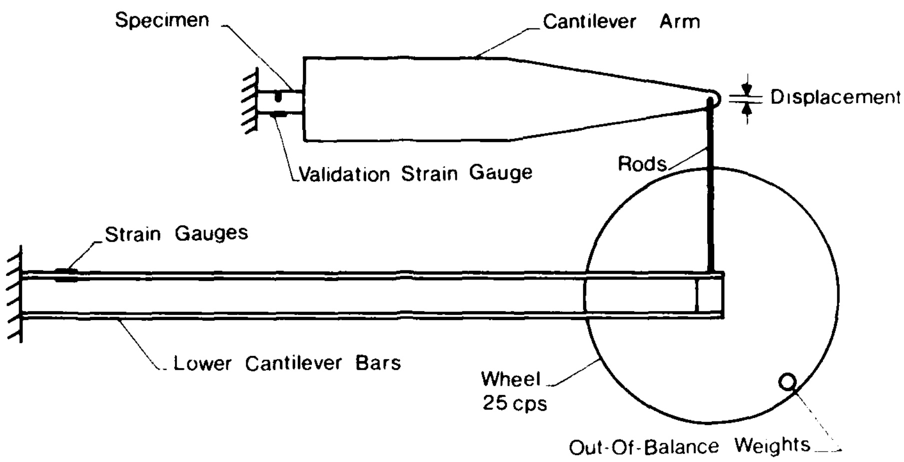

FIG. 1 - Schematic drawing of the NPL machine showing the locations of strain gauges used in the work.

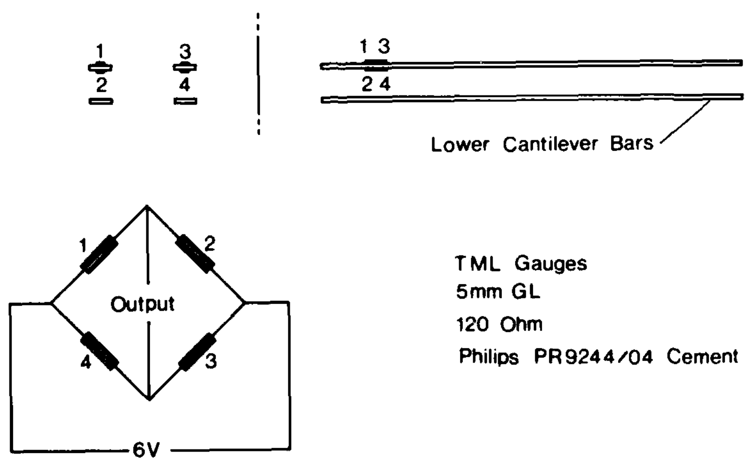

FIG. 2 - The strain bridge configuration for the instrumentation of the NPL machine.

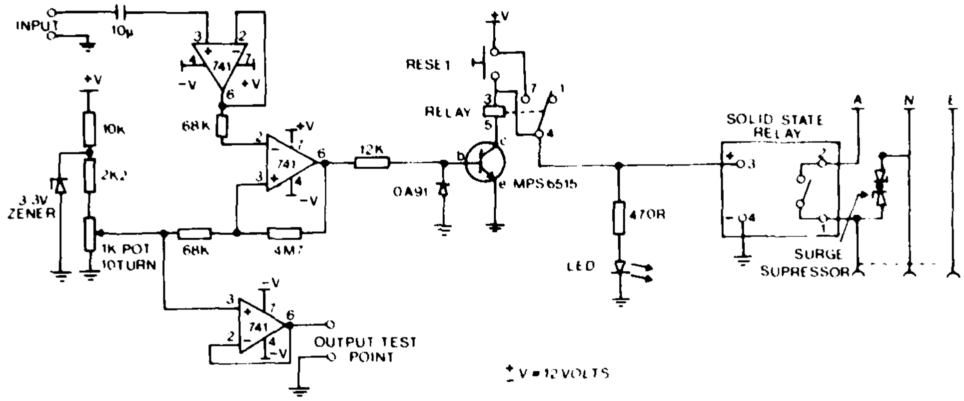

FIG. 3 - Schematic diagram of peak voltage detector and automatic switch-off circuit.

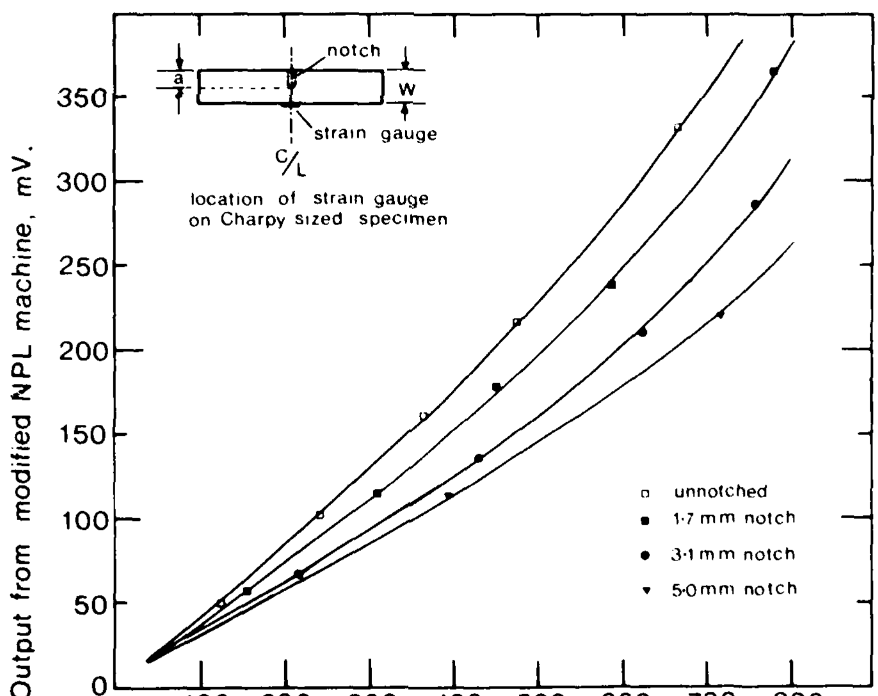

FIG. 4 - Graph of the AC RMS output from the NPL machine plotted against the outputs from the strain gauges mounted on the specimens. The location of the strain gauge on the specimen is shown in the inset figure.

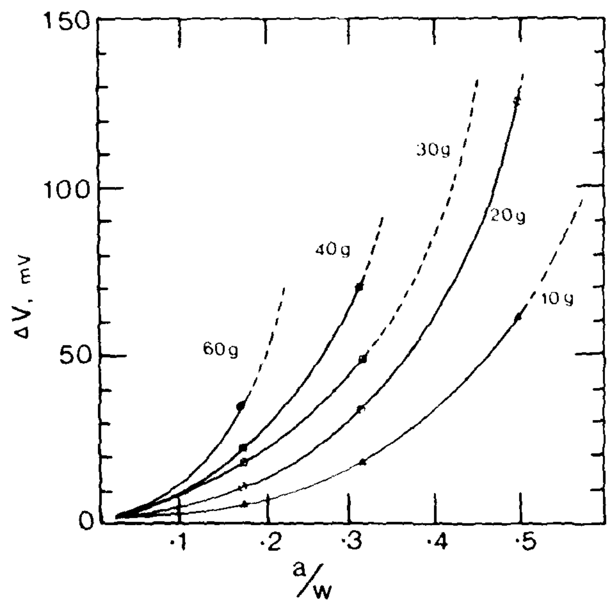

FIG. 5 - Graph of the difference in AC RMS voltage level from the strain gauges on the NPL machine plotted against a/w for a range of out-of-balance weights.

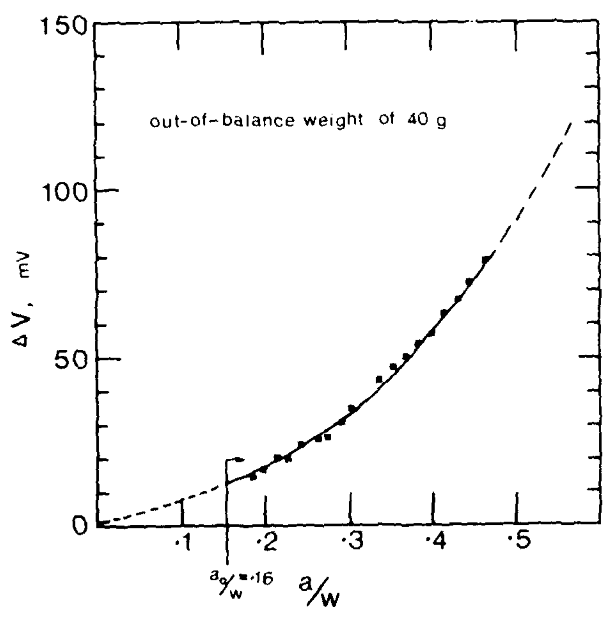

FIG. 6 - Graph of the change in AC RMS voltage level from the strain gauges on the NPL machine plotted against a/w for an out-of-balance weight of 40 g. The initial notch depth was 1.6 mm.

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